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Underground Cable Fault Analysis by Distance Calculation and Location Detection using Microcontroller and GPS

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Abstract

In today's power distribution systems, underground cables are preferred for their safety and tidy appearance. However, detecting faults in these cables can be slow, costly, and technically challenging. This study introduces a smart fault detection and location system that uses the PIC16F887 microcontroller as its core. It sends a low DC voltage through the cable and uses voltage and current sensors to monitor for irregularities. Based on the changes in readings, the system estimates the fault distance using Ohm's Law. To pinpoint the exact location, a GPS module is included. The fault details are shown on an LCD and also transmitted through GSM for SMS alerts. Additionally, the ESP8266 Wi-Fi module allows the data to be shared online for remote monitoring. This solution provides faster and more accurate fault detection, reducing repair time and improving the reliability of underground cable systems.

Keywords: PIC16F887, ESP8266, GSM, Voltage Sensor, Current Sensor, GPS.

1. Introduction

Underground cables are used to transmit electricity and data safely and securely. However, these cables can sometimes get damaged, leading to power failures or interruptions in service. Since the cables are buried, locating the fault can be difficult and time-consuming.

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Traditional methods, such as physical inspection, are often slow and not very accurate. To solve this problem, a more efficient and precise method is needed. This study presents an advanced solution that uses a microcontroller along with GPS technology. The microcontroller collects data from sensors and works with the GPS to pinpoint the fault's exact location. This system helps technicians find and fix the issue faster, saving time and reducing repair efforts.

2. Related work

Detecting and locating faults in underground power cables is a crucial challenge in power distribution systems, prompting research into more efficient alternatives to time-consuming and inaccurate traditional methods. Several studies have explored analysis-based approaches, such as using Fourier analysis to detect faults and estimate cable life [1, 10] and employing complex wavelet analysis for cable identification [5]. Microcontroller-based systems, often utilizing microcontrollers like the PIC16F887 and ATmega 328P, have also been developed to automate fault detection and location by applying Ohm's Law [2, 3, 4]. These systems calculate fault distance using voltage and current measurements, offering improved accuracy. Recent advancements include integrating IoT for remote monitoring and cloud storage [7, 8], as well as employing techniques like sectionalizing, thumper, and time domain reflectometry with MATLAB simulations [6]. Researchers have also investigated methods for incipient fault detection and impedance-based fault location to enhance system robustness [11]. Despite these advancements, challenges such as fault location inaccuracy and the need for cost-effective, durable solutions remain critical areas for future research [2, 9].

The proposed system to detect the underground faults was designed based on the related works carried out using the PIC microcontroller, sensors , GSM and GPS.

3. Proposed Work

This system is designed to continuously monitor underground electrical cables, identifying faults like short circuits and open circuits in real time using voltage and current measurements. The core of the system is a microcontroller that collects data from sensors, including voltage, current, and GPS, to detect faults and determine their exact location. The GPS module provides precise fault location tracking along the cable, aiding quick diagnostics and efficient maintenance. By calculating impedance or analyzing signal delays, the system estimates the distance from the monitoring point to the fault. The results are displayed on an

LCD screen and sent to a central monitoring platform. Wireless communication through GSM transmits fault details to technicians. The system also logs data for long-term analysis and features an intuitive user interface for both local and remote monitoring. Automatic activation of switches isolates the faulty section to prevent further damage. Energy efficiency is prioritized, and the system provides immediate alerts with GPS information. Figure 1 shows the block diagram of the proposed system.

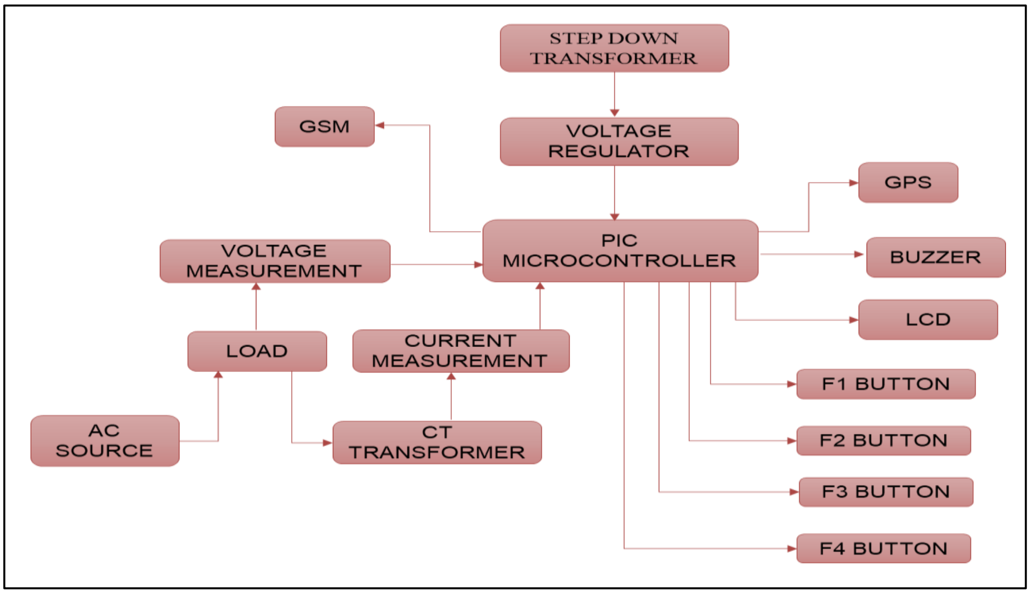

Figure 1. Block Diagram of the Proposed System

Table 1. Components Used

Component	**Range**	**Unit**	**Description**
PIC16F887 Microcontroller	Up to 20 MHz Clock Speed	MHz	Central control unit that reads sensor data, processes information, and manages outputs.
Step-Down Transformer	Input: 230V AC → Output: 12V AC	Volts	Converts high-voltage AC supply to a safer low-voltage level for circuit use.
AC to DC Converter	Converts 12V AC to 5V DC	Volts	Supplies stable DC voltage required for operating digital components.

GPS Module	Accuracy: 2.5 – 5 meters	Meters	Locates the exact position of the cable fault based on geographical data.
IOT Module (e.g., ESP8266)	WiFi Frequency: 2.4 GHz	GHz	Sends collected data wirelessly to a cloud or monitoring system.

Table 1 depicts the components used in detecting the underground cable faults. The details of the components used are as follows:

- **Stepdown Transformer**

A step-down transformer (Figure 2) lowers high voltage from the primary side to a lower voltage on the secondary side. It is commonly used in devices like electronics, chargers, and power distribution systems. These transformers make high voltages (like 230V or 120V) safe for small devices by converting them to lower values such as 5V. In power networks, they reduce voltage in stages, from 765 kV to 220 kV, to ensure efficient and safe transmission. Large units handle high power (up to 1000 MVA), while smaller ones (under 5 MVA) serve residential areas.

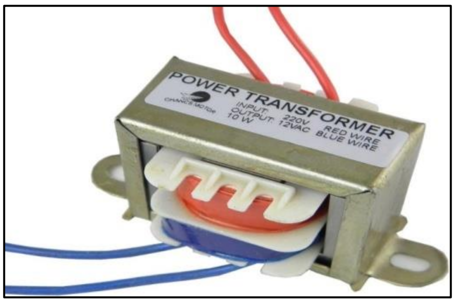

Figure 2. Stepdown Transformer

- **Voltage Regulator 7805**

The circuit in Figure 3 works in two main stages: converting AC to DC and regulating the DC voltage. Initially, a step-down transformer lowers the 230V **AC** mains supply to **9V**

AC. This lower AC voltage is then passed through a bridge rectifier to convert it into a pulsating DC output. To smooth out this DC, a 470µF capacitor is connected, resulting in an unregulated 9V DC supply. This unregulated voltage is fed into a 7805 voltage regulator IC, which outputs a constant 5V DC,ideal for powering devices that require low and stable voltage levels. For the 7805 to function correctly, the input voltage must be slightly higher than 5V. Typically, if the input is around 7.5V at 1.5A, the output will be 5V at 1.5A, with the extra voltage being released as heat. Such circuits are widely used in regulated power supplies for microcontrollers, sensors, and other digital devices.

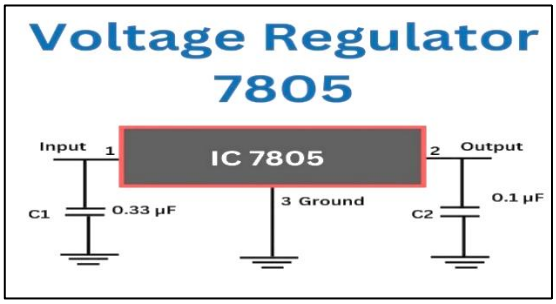

Figure 3. Voltage Regulator 7805

- **Current Regulator**

Current measurement is essential in electrical engineering to monitor the flow of electric charge in a circuit. Measured in amperes (A), current is crucial for ensuring devices run safely and efficiently. Accurate current measurement (Figure 4) helps detect problems, prevent overloading, and maintain system reliability. Common methods include using an ammeter with a low-resistance shunt resistor to measure the voltage drop and calculate current using Ohm's Law. Another method is using Hall Effect sensors, which generate a voltage proportional to the current. These techniques provide precise monitoring for various electrical applications.

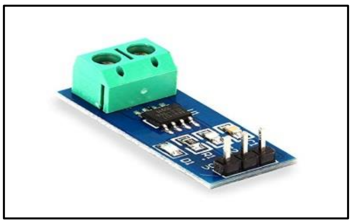

Figure 4. Current Regulator

- **AC to DC Converter**

AC to DC converters (Figure 5) are important in power electronics because many devices need DC power to work. These converters change AC (alternating current), which flows back and forth, into DC (direct current), which flows in one direction. This process is called rectification. A rectifier is used to convert the AC input into a DC output. Transformers are also used to reduce the AC voltage to a suitable level before converting it to DC. Generators produce AC and have a changing direction, while DC is produced by batteries or DC generators and flows steadily in one direction without changing.

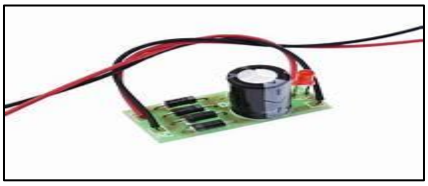

Figure 5. AC to DC Converter

- **GPS**

The module has a NEO-6M-0-001 GPS (Figure 6) engine with ROM 7.0.3 and supports 3.3V–5V input. It includes a UART interface with a default baud rate of 9600 for serial communication. The GPS signal is right-hand circular-polarized, so a patch antenna is used. This antenna is flat and should face the sky for the best signal reception.

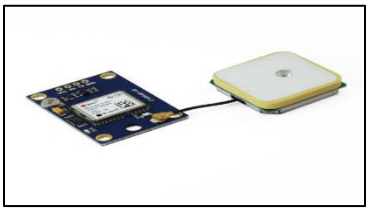

Figure 6. GPS

- **PIC16F887 Microcontroller**

The PIC16F887 (Figure 7) is an 8-bit microcontroller that uses RISC architecture for efficient performance with low power consumption. It comes in a 40-pin package and offers multiple I/O ports (A to E), supporting TTL/CMOS logic levels. The microcontroller features serial communication through EUSART, utilizing two pins for data transmission and reception. It includes three timers: Timer0 and Timer2 (8-bit) and Timer1 (16-bit), supporting both internal and external clock sources. Timer1 also allows a third clock input and has a gate control feature. The microcontroller is designed for flexibility, making it suitable for various embedded applications.

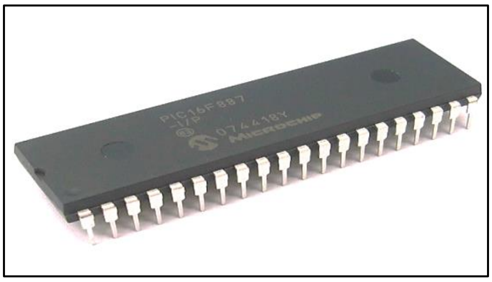

Figure 7. PIC16F887 Microcontroller

- **LCD Display**

LCD (Figure 8) stands for Liquid Crystal Display, a type of electronic display used in many devices like mobile phones, calculators, computers, and TVs. It is popular for displaying information using multi-segment LEDs and seven-segment displays. LCDs are preferred because they are affordable, easy to program, and can show custom characters, special symbols, and even animations. These displays provides flexibility and are widely used in various applications due to their cost-effectiveness and versatility.

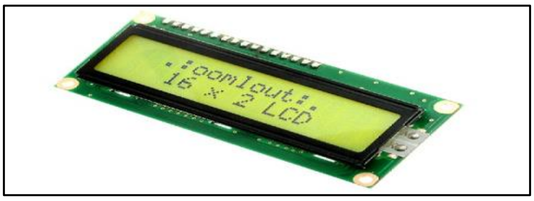

Figure 8. LCD Display

- **GSM**

The GSM module (Figure 9) in the underground cable fault detection system serves to transmit fault details via SMS alerts. When a fault is detected, the system uses the GSM module to send a text message containing information about the fault's location and other relevant details to the user or maintenance personnel.

Figure 9. GSM

- **Buzzer Alarm**

The operation of a buzzer (Figure 10) is based on the piezoelectric effect, where applying a voltage across a piezoelectric material causes it to change shape slightly. A piezo buzzer typically consists of piezoelectric crystals placed between two conductive plates. When an fault is detected, the electric voltage is applied, the crystals expand and contract due to their internal properties. This movement causes one of the plates to be pushed and pulled rapidly, creating vibrations. These vibrations generate sound waves, resulting in the high-pitched tone or buzzing sound. The repeated movement of the crystals in response to the alternating voltage leads to a continuous sound signal.

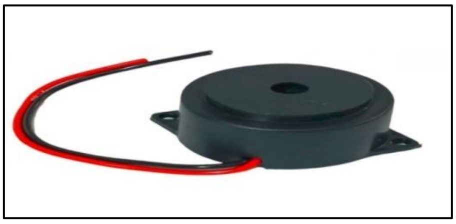

Figure10. Buzzer Alarm

4. Circuit Diagram

This study presents a system that helps monitor and detect electrical problems in medium and high-voltage underground cables. It uses voltage and current sensors, voltage converters, and a microcontroller to check the health of the cable. Sensor units are placed every one kilometer along the cable route. These units constantly measure voltage levels and send the data to a central control unit. A PIC microcontroller is used to collect, store, and analyze this information. When abnormal voltage is detected, the system can trigger safety actions. A step-down transformer lowers high input voltage to a safer level, while a step-up transformer helps balance the voltage output across the cable network. The system includes a GPS module to find the exact location of the fault. This makes it easier for repair teams to locate and fix the issue quickly. An ESP8266 Wi-Fi module connects to a PIC16F877A microcontroller, which displays the cable's status and shows the distance to any detected fault, helping improve monitoring and maintenance.

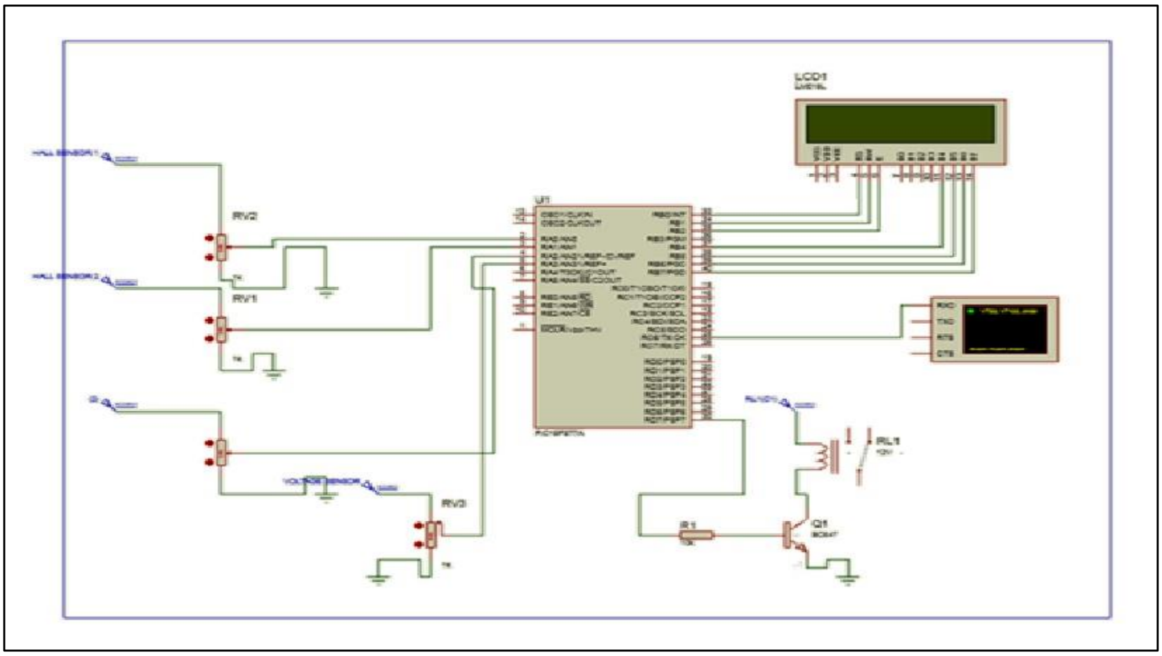

Figure 11. Circuit Diagram

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5. Working Methodology

This study introduces a system designed to monitor electrical stress in medium and high-voltage underground cables. The system incorporates current and voltage sensors along with microcontroller technology. Monitoring devices are installed every kilometer along the cable network to measure voltage stress and evaluate cable performance. The data collected by these sensors is transmitted to a central unit where a PIC microcontroller processes and stores the information. If irregular voltage patterns are detected, the system activates the necessary actions. Voltage regulation is managed by a step-down transformer at the input to maintain the system's balance. Additionally, the network uses GPS to pinpoint the exact location of voltage issues, aiding maintenance efforts by providing precise fault locations.

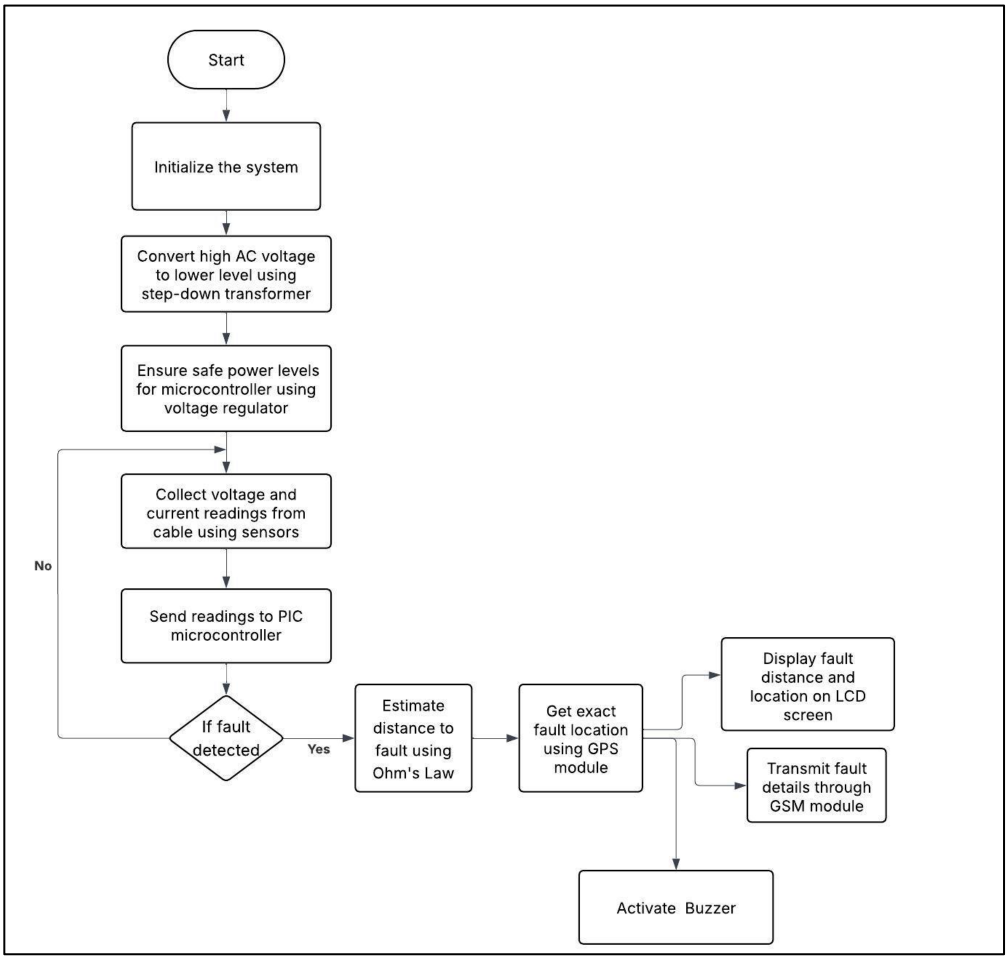

Figure 12. Workflow for Detecting the Underground Cable Faults

The system also integrates an ESP8266 IOT module with a PIC16F877A microcontroller, which displays the status of each cable phase and provides the distance to any fault within the underground network. The flowchart in Figure 12 depicts the workflow for detecting the underground cable faults.

The distance is measures using the following Equation 1 given below:

$$Distance = \left(\frac{Measured\ Voltage\ Drop}{Supplied\ Voltage}\right) * Length\ of\ Cable \quad (1)$$

6. Results

The underground cable fault detection system has been successfully deployed, combining microcontroller technology with GPS functionality to pinpoint precise fault positions. The implementation achieves high-precision fault identification in underground cable networks through resistance-based measurement methodologies. The microcontroller component analyzes voltage and current fluctuations in real time to identify and categorize fault conditions. Location identification utilizes GPS technology to establish the exact geographical coordinates of detected faults. This spatial data appears on an integrated LCD and can be transmitted to centralized monitoring facilities, substantially enhancing maintenance response efficiency and reducing downtime. The prototype of the hardware implementation is depicted in Figure 13.

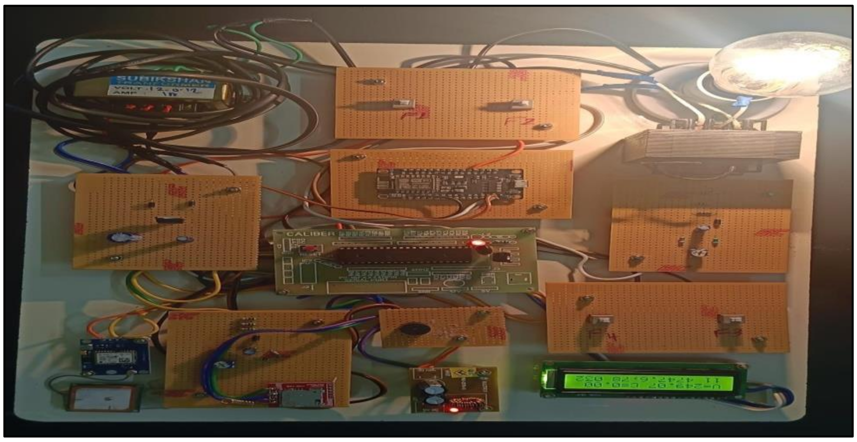

Figure 13. Prototype Hardware Implementation

Figure 14. Output in IoT BLYNK

The ThingSpeak channel dashboard displays (Figure 14) real-time monitoring data for a system involving electrical parameters. The four field charts represent measurements for voltage, current, and underground (UG) cable activity. The voltage chart shows relatively stable readings, mostly fluctuating between 200 and 250 volts, suggesting a consistent power supply. In contrast, the current and UG cable charts exhibit a sharp spike around 18:00, indicating a sudden change in load or a possible disturbance in the system. These spikes are short-lived, returning quickly to baseline values, which may point to a transient event such as a switching operation or a brief fault. The repetition of similar spikes in both UG cable fields suggests that the event affected multiple points in the monitoring system. Overall, the data suggests normal operation with a momentary anomaly that may warrant further inspection depending on system sensitivity."

Figure 15. Output in LCD Display and Message

Figure 15, display sensor readings and alert messages related to electrical parameters such as voltage and current. The first display shows a high voltage of 374.19V with zero current, while the second shows a normal voltage of 235.77V and a current of 5.10A. Based on these readings, alert messages are triggered. One warning indicates a high voltage condition, while another signals either excessive current or a possible short circuit. Both alerts include GPS coordinates, allowing quick identification of the event location. This suggests the system is actively monitoring for electrical faults and promptly reporting them for safety and maintenance purposes.

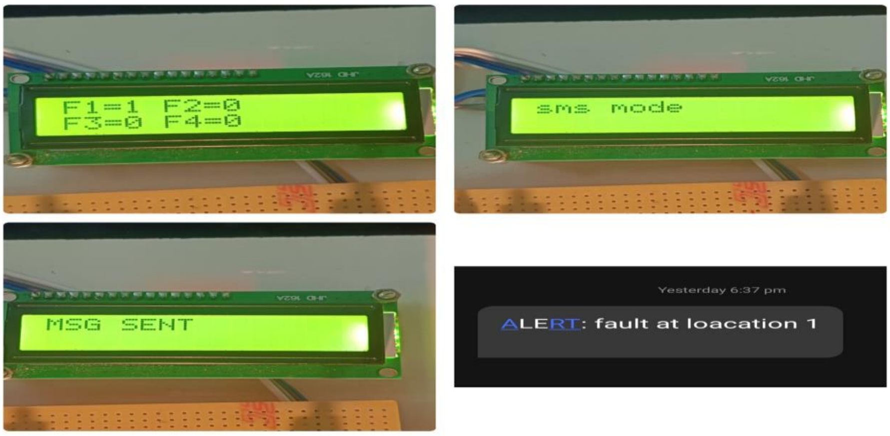

Figure 16. Output in Location Fault Detection

Figure 16 illustrate a fault detection system in action. The LCD display indicates that Fault 1 (F1) is active while the others remain inactive. Upon detecting the fault, the system switches to SMS mode and sends a notification, as confirmed by the "MSG SENT" message. A corresponding alert is received through SMS, stating there is a fault at location 1. This setup shows that the system can accurately identify specific fault zones and immediately notify users through mobile alerts, enhancing response time and safety. The process is efficient and supports real-time monitoring for quick fault isolation and action.

7. Conclusion

This research demonstrates how embedded systems can be used to monitor and detect voltage stress in medium and high-voltage underground cable networks. The system effectively uses the I2C communication protocol for reliable data exchange between components. It features a PIC16F877A microcontroller working with an ESP8266 IoT device in a master-slave setup to process and send key measurements. Voltage regulation is achieved through step-up and step-down transformers to manage abnormal voltage conditions in the underground cables. The system can identify different faults, such as short circuits, voltage drops, and excessive voltage, at specific points in the network using principles based on Ohm's Law. This method helps diagnose and fix problems efficiently, providing significant benefits for managing and maintaining underground cable systems.

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